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ABSTRACT

Arguing that sufficient theory exists about the interplay between human information processing, computer systems, and the demands of various tasks to construct useful theories of human-computer interaction, this study presents a structural model of human-computer interaction and reports the results of various statistical analyses of this model. Male and female subjects (N=109) were asked to complete the numerical, spatial, and logical subscales of the California Test of Mental Maturity (CTMM), which represented measurable variables, and their total scores were used to indicate various latent variables of the model, including decision time and errors. Upon completing the CTMM, subjects solved a variety of problems presented via computer, i.e., locating a number, interpolation, forecasting, and trend analysis. Mean problem-solving times for each of the four problem types were used as indicators of the decision time latent variable, and the average number of errors for each of the four problem types served as indicators of the errors latent variable. A correlation matrix of the measured variables was computed and analyzed with LISREL VI. A sub-model of the primary model of human-computer interactions was used to assess the relationship between various measures of intelligence and problem-solving behavior. Statistical tests--chi-square, goodness-of-fit index, rho, and the root mean square residual--were used to test the hypothesis that the model was plausible for explaining the relationships that existed in the data. Chi-square for the model indicated that the model did not fit the data. However, a final model presented in the study fit quite nicely according to both inferential and descriptive tests. Three researcher biographies and three figures--a causal user model, the structural model that was tested, and the final causal model--are included. (4 references) (CGD)

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Modeling Human-Computer Decision Making with Covariance Structure Analysis

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Introduction

The development of a complete theory of human-computer interaction has been hindered by the lack of full scale testable models. To date, those models which have been tested are primarily low-level (e.g., key-stroke; Card, Moran, & Newell, 1983). Although providing clear predictions, they rarely provide information on more than just a few low level variables. Other models, such as those provided by mental representations (e.g., Gentner & Stevens, 1983), are often not testable or do not provide quantified information concerning the importance of variables and their interrelations.

We argue there exists sufficient theory regarding the interplay between human information processing, computer systems, and the demands of various tasks to construct useful theories of human-computer interaction. Furthermore, we can statistically test these models, their parameters, and competing models through the application of covariance structure modeling (Joreskog & Sorbom, 1984).

Figure 1 presents one model of human-computer interaction which might be constructed. The model specifies various latent variables (in circles) and their interrelations, for a decision making task. As the model illustrates, the USER, SYSTEM, and TASK are the central endogenous latent variables and are each reciprocally related to the others. The ENVIRONMENT is the only exogenous latent variable and the model specifies a causal uni-directional effect by it on the three core latent variables.

A second group of endogenous latent variables is also specified in Figure 1. These include DECISION TIME, ERRORS, and PREFERENCE. The directional relations among these and the other latent variables are also specified by the model.

Since latent variables cannot be directly measured, measured variables must serve as indicators of the latent variables. As an example, to reflect the USER latent variable of Figure 1, measures of previous computer experience (background), attitude toward computers (computer att), and three measures of intelligence (spatial, logical, and numerical ability) are utilized. With this type of statistical modeling, it is important the measured variables are relatively free of error of measurement and unique factors, thereby reflecting only the

latent variable of interest.

The present study reports the results of a sub-model of Figure 1. This structural model is presented in Figure 2. Our present interest is in assessing the relationship between various measures of intelligence (spatial, logical, and numerical ability) and problem solving behavior (time-to-decision and errors).

Method

Male and female subjects (N = 109) participated in the study. Subjects first completed the numerical, spatial, and logical subscales of the California Test of Mental Maturity (CTMM). Total scores on these tests were used to indicate the numerical, spatial, and logical latent variables of the model, respectively.

Upon completing the CTMM, subjects solved a variety of problems presented via computer. Four different types of problems were used: locating a number, interpolation, forecasting, and trend analysis. These were selected for inclusion in the study because they are representative of the types of problems confronted by managers in most organizations. Subjects solved several problems of each of the four problem types. Presentation order of the problems was counterbalanced and reaction time was measured by a hardware clock in the computer.

Mean problem solving times for each of the four problem types were used as indicators of the decision time latent variable. Average number of errors for each of the four problem types served as indicators of the errors latent variable. A correlation matrix of the measured variables was computed and analyzed with LISREL VI (Joreskog & Sorbom, 1984).

Model Testing.

Determining the fit of the model to the data is performed at both inferential and descriptive levels. Inferentially, a chi-square test is provided of the hypothesis that the model is a plausible one for explaining the relationships which exist in the data. A non-significant chi-square indicates the model is statistically plausible whereas a significant chi-square suggests that the model cannot statistically explain the relationships found in the data.

Utilization of this technique requires a large sample for stability of parameter estimates. A large sample, however, will almost always ensure a significant chi-square. Therefore several practical measures of fit are employed. These include rho and the goodness of fit index (GFI), each of which should equal or exceed .9 to reflect acceptable practical fit of the model to the data.

A final descriptive measure of fit is the root mean square residual (RMR). RMR reflects the average amount of residual variance which is not being explained by the model. Generally,

RMR shculd be less than .1 in a good fitting model.

Results

The structural model specified in Figure 2 was tested. The chi-square for the model was significant ($p < .04$) indicating that statistically the model did not fit the data. Specification searches (MacCallum, 1986) led to the elimination of the paths between numerical and spatial ability and decision time. Each path was less than .02 in magnitude and t-tests supported the argument that neither was significantly different from zero in the population. A large modification index on the error measured variable for interpolation problems suggested the parameter should be estimated, thereby reflecting the decision time latent variable. Since the relationship between errors and reaction time is a well documented psychological phenomenon, this modification was allowed on theoretical grounds.

The final model presented in Figure 3 fit quite nicely according to both inferential and descriptive tests. The inferential chi-square with 38 degrees of freedom is 50.78, $p < .08$, indicating that statistically this is a plausible model. Practical measures of fit also are quite good, rho = .94, and GFI = .93. The RMR of .06 is well below its critical value of .1.

Discussion

This research holds several important implications for researchers and practitioners in the area of human-computer interaction. First, it demonstrates that theories of the interrelationships among variables important in a human-computer cooperative task can be specified and tested. Second, and somewhat not surprising, is that alternate types of intellectual ability are differentially important within the problem solving domain. Relying on this type of knowledge. information display specialists could focus on the optimum manner of displaying problem specific information to different user groups. Third, inclusion of additional latent variables such as those found in Figure 1 would be important information for system designers to consider when determining the relative importance of other features of computer supported cooperative tasks for various user groups. Our current research is focused on the development and testing of a variant of the model presented in Figure 1.

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Michael D. Coovert is an assistant professor of psychology at the University of South Florida. He received a B.A. in computer science and psychology from Chaminade University of Honolulu, an M.S. in psychology from Illinois State University, and a Ph.D. in psychology (with a minor in computer science) from The Ohio State University. Dr. Coovert's research interests include quantitative methods, human-computer interaction, cognition, and artificial intelligence.

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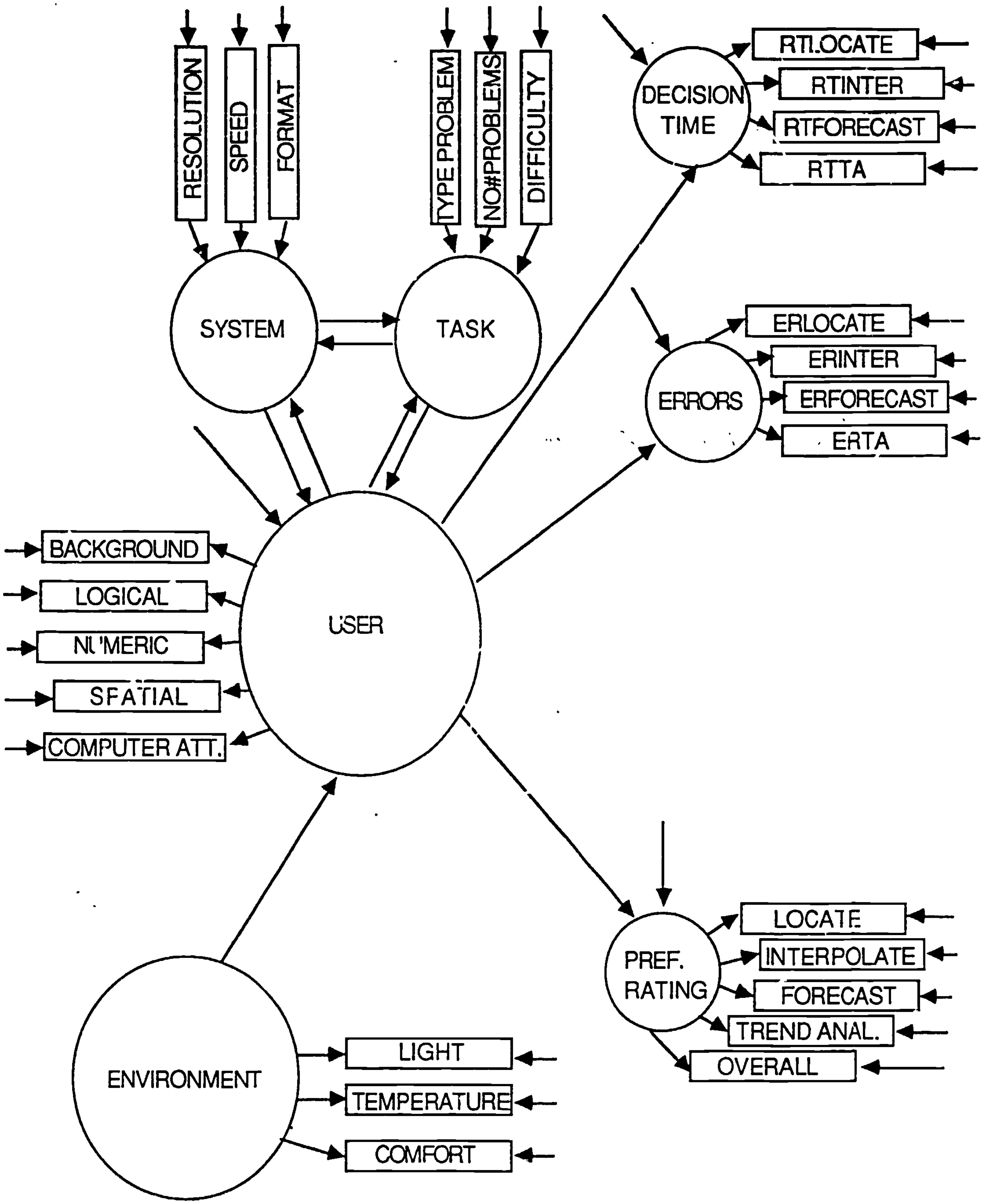

Figure 1. Causal User Model

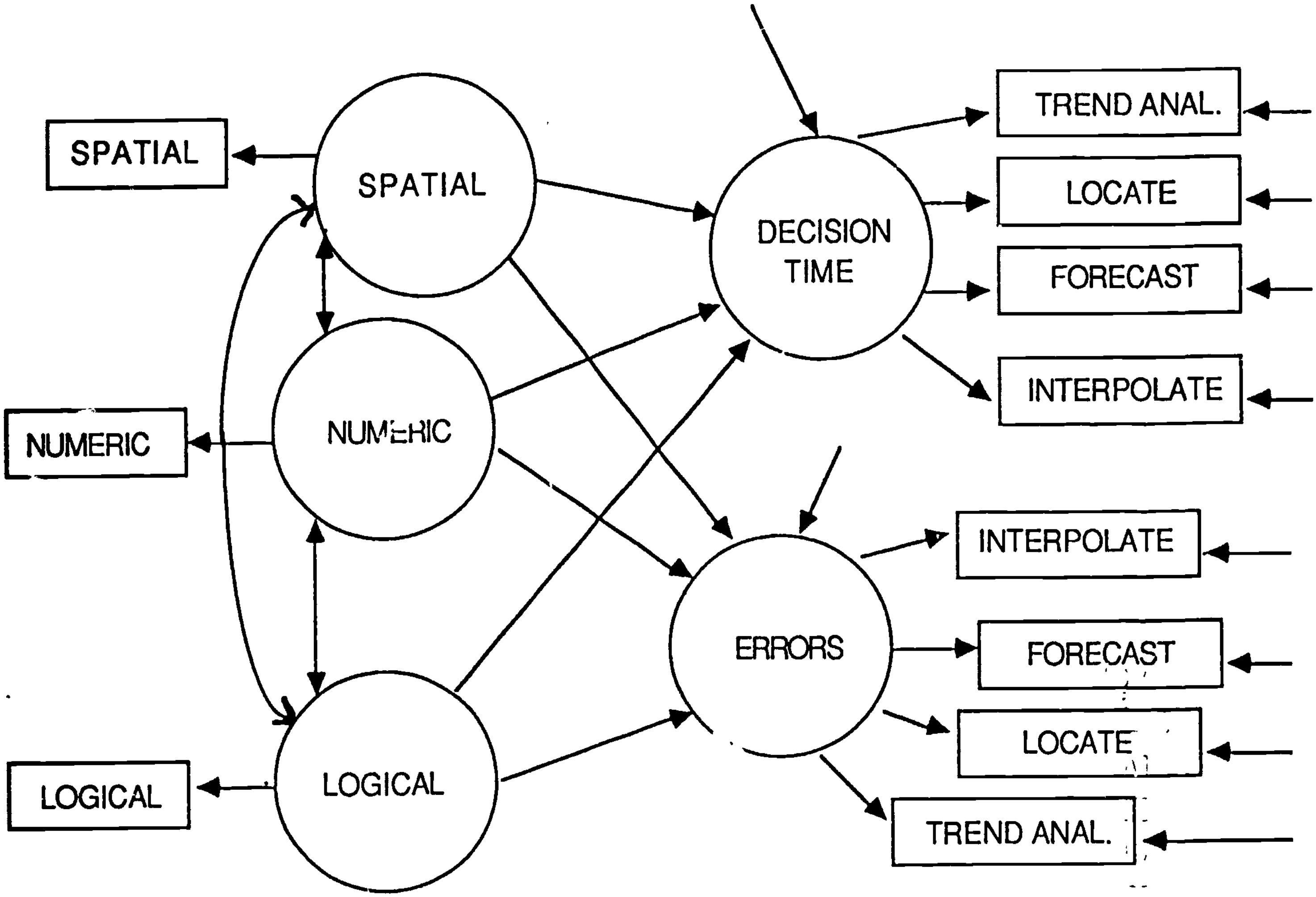

Figure 2. The Structural Model that was tested.

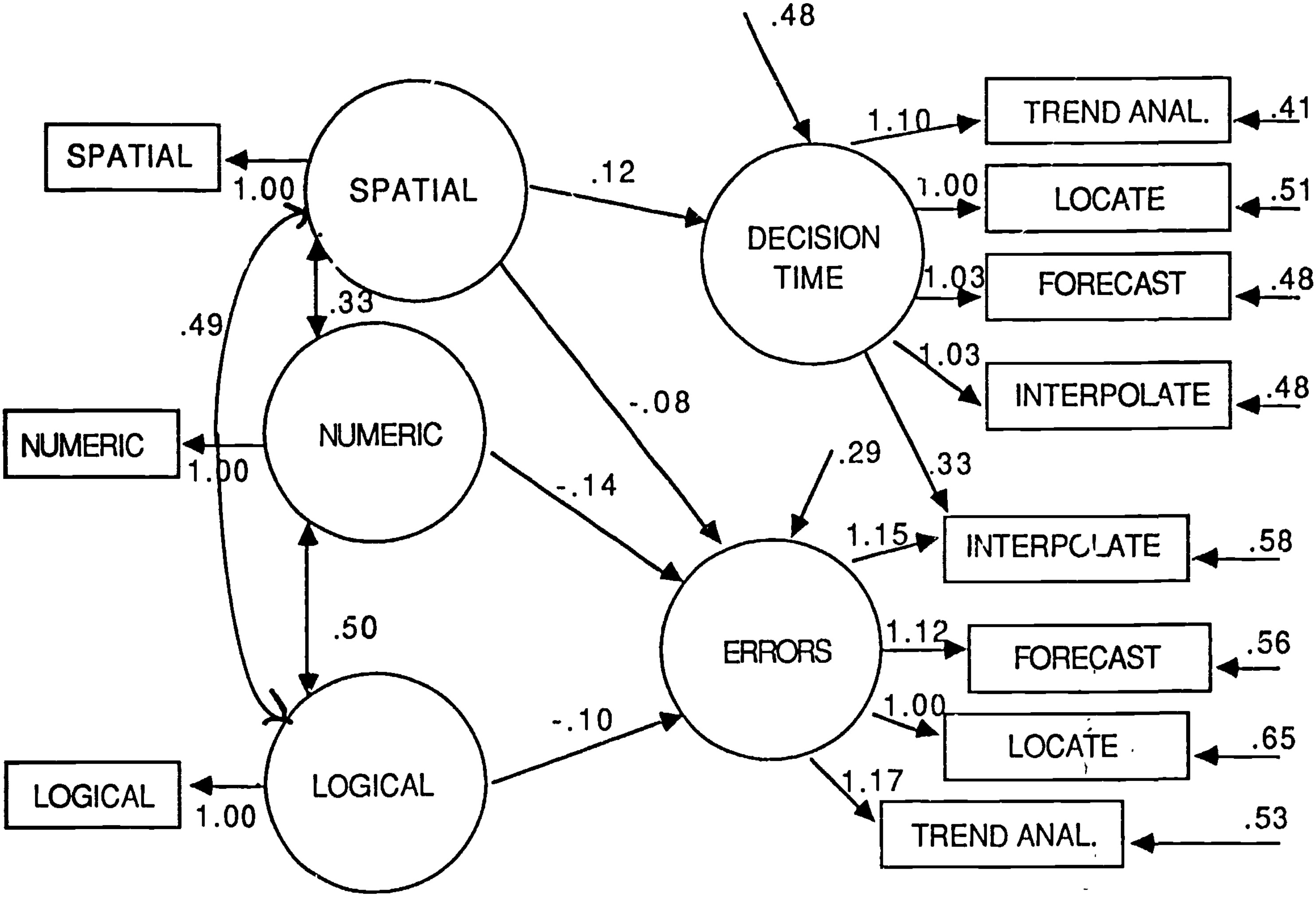

Figure 3. The Final Causal Model